FRDA REPORT 139

FOREST HARVESTING AND RENEWAL PLANNING FOR THE BRITISH COLUMBIA INTERIOR: AN EXTENSION OF THE TOTAL-CHANCE CONCEPT

by

R.E. Breadon, R.P.F.

Contractor: Forest Engineering Research Institute of Canada
2601 East Mall
Vancouver, B.C.

Departmental Representative:
Glenn H. Manning
Pacific Forestry Centre
Forestry Canada
506 W. Burnside Road
Victoria, B.C.

September 1990

This report has been reviewed by Forestry Canada and approved for distribution. Approval does not necessarily signify that the contents reflect the views and policies of Forestry Canada. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

ISSN 0835-0752
ISBN 0-662-18158-1
Fo29-19/139E
Abstract

Handbook No. 9 is a sequel to Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept*, which was published by the Forest Engineering Research Institute of Canada (FERIC) in 1983. Handbook No. 4 described the steps required at that time to prepare a total-chance harvesting development plan, using the fictitious Rainbow Creek (in British Columbia) as a model. Handbook No. 9 describes how timber-development operations might have progressed since 1983, and what new factors must be incorporated into onward planning in response to new technologies, attitudes, guidelines, and policies affecting forest management.

A new plan and operating schedule illustrates how the Rainbow Creek road-construction and harvesting programs should continue under new constraints. To this is added a detailed plan and schedule for forest-renewal operations, now the direct responsibility of the forest company. Examples show how all operations can be integrated for best field results and profitability.

The remarkable capabilities of recent geographic information system (GIS) technology are demonstrated, as planning progresses through the stages of initial preparation, optimization, review, modification, presentation, and approval.

Acknowledgements

- John Murray and the Nelson Steep Slopes Committee (now superseded by the British Columbia Interior Forest Harvesting Subcommittee for the Nelson Forest Region), for long-term support of the total-chance concept, which led in 1983 to the publication of FERIC Handbook No. 4.
- Alex Sinclair of FERIC and Glenn Manning of Forestry Canada, for seeing the value of revisiting FERIC Handbook No. 4 and the mythical Rainbow Creek.
- Selected harvesting and silvicultural specialists in the forest industry and government, throughout the forest regions of British Columbia, for outlining their local experience in planning and conducting integrated harvesting and silvicultural operations. FERIC contacted these people through personal visits and/or by telephone. Their names appear in Appendix IV.
- Andrew Mitchell of the British Columbia Ministry of Forests, for demonstrating that the right geographic information system can be of immense value for creating and refining total-chance plans.
- Bela Hirczy and Ted Turner of the British Columbia Ministry of Forests, for enthusiastic support, and for making available a set of *Harvest Management System* data, already digitized from the maps in FERIC Handbook No. 4.
- Jack MacDonald of FERIC, for masterfully manipulating the *Harvest Management System* to produce the necessary maps and printouts.
- Ingrid Hedin, Marv Clark, Kathy Prochnau, Jennifer Tan, and Kathi Patton, all of FERIC, for indispensable help in preparation of this report.
- Dave Haley (Forestry Canada); Jim Maxwell, Dave Lawrie, and Andrew Mitchell (British Columbia Ministry of Forests); Wayne Morrison (Crestbrook Forest Industries Ltd.); John Mansell (Weldwood of Canada Limited) and Jean-François Gingras and Denis Cormier (Eastern Division of FERIC), for thoughtful and helpful reviews of the draft report.

Author

Robert Breadon was, until his retirement in March 1990, a Senior Researcher in FERIC’s Western Division in Vancouver. He holds Forestry degrees from the University of British Columbia and Duke University, and is a Registered Professional Forester in the province of British Columbia.

Disclaimer

This report is published solely to disseminate information to FERIC members. It is not intended as an endorsement or approval by FERIC of any product or service to the exclusion of others that may be suitable.
# Table of Contents

Abstract iii  
Acknowledgements iii  
Author iii  
Summary ix  

INTRODUCTION 1  

RAINBOW CREEK REVISITED 1  

EVENTS SINCE 1984 2  
  Road Construction 2  
  Harvesting 2  
  Changing Players 3  
  Integrated Resource Management 3  
  Forest-Renewal Operations 4  
  GIS Breakthrough 4  

NEW RAINBOW CREEK PLAN, 1990+ 5  
  Completion of PASS 1 Road Construction 5  
  Completion of PASS 1 Harvesting 7  
  Forest-Renewal Program (PASS 1 Openings) 24  
  Optimizing Harvesting and Forest-Renewal Plans 32  
  PASS 2 Planning 37  
  Checking, Reviewing, Modifying, and Approving 37  
  Cutting Permit Application 38  

DISCUSSION 39  

CONCLUSIONS 39  

REFERENCES 40  

OTHER READING 41  

APPENDICES  
  I  Annual Expenditures on Road and Bridge Construction 42  
  II  1989 Logging Costs 44  
  III  Forest-Renewal Program, Scheduling, Costs 48  
  IV  List of Organizations and Individuals Contacted 50
List of Tables

1 Road-Completion Schedule and Budget 8
2 Harvesting Areas and Volumes 17
3 Harvesting Schedule, Remainder of PASS 1 (1990-92) 18
4 Harvesting Equipment: Direct Costs, 1990-92 21
4a Road-Construction and Road-Maintenance Equipment:
   Direct Costs, 1990-92 21
5 Calculation of Machine Requirements, CABYARD
   SYSTEM 1990 23
6 Calculation of Equipment Needs for Road-Construction
   and Road-Maintenance Programs 1990 23
7 Forest Types and Biogeoclimatic Subzones 27
8 Annual Expenditures on Forest-Renewal Program, PASS
   1 Blocks, 1987-2006 32
9 Forest-Renewal Requirements and Costs, 1990-92 33
10 Estimated Direct Harvesting Costs, CABYARD and
   CHOSKID 1990 36
11 Forest-Renewal Costs for Block 90.02 36

List of Figures

1 Machines required for constructing and maintaining
   log-hauling roads 6
2 FELBUNCH system, suitable for harvesting small timber
   on moderate terrain 10
3 MEDCRAWL system, suitable for harvesting large timber
   on broken terrain with adverse skidding 11
4 CHOSKID system, suitable for harvesting a range of
   timber sizes on moderate terrain with firm or
   frozen ground 12
5 SMCRAWL system, suitable for harvesting small timber
   on steep slopes with short skids and small landings 13
6 CABYARD system, best suited for harvesting large
   timber on steep terrain, but can also be used with
   small timber 14
7 LGPSKID system, suitable for harvesting small timber
   on steep and regular terrain 15
8 Main forest-renewal treatments prescribed for Rainbow
   Creek 25
9 Typical scheduling of post-harvesting surveys and
   forest-renewal treatments 28
10 Block 90.02: CHOSKID harvesting system replacing
   original CABYARD 35
<table>
<thead>
<tr>
<th></th>
<th>List of Maps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Topography and Timber Types</td>
</tr>
<tr>
<td>2</td>
<td>Roads and Harvesting Operations</td>
</tr>
<tr>
<td>3</td>
<td>Reforestation Operations</td>
</tr>
<tr>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>xii</td>
</tr>
<tr>
<td></td>
<td>xiv</td>
</tr>
</tbody>
</table>
Summary

In 1983, the Forest Engineering Research Institute of Canada (FERIC) published Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept*. It described the efforts of an imaginary forest company to create a timber-development plan for the fictitious Rainbow Creek drainage in British Columbia. The handbook was well received as a checklist of the many steps needed "to eliminate all the uncertainties which can be eliminated, and to deal wisely with the ones which remain" (Breadon 1983).

Momentous changes have since occurred in British Columbia’s Crown forest policies, in industrial forest-management objectives and responsibilities, in public attitudes toward forests, and, of course, in the forests themselves. This new Rainbow Creek report extends the total-chance concept to include silviculture and all other resource programs affecting a forest. Applied computer technology, i.e. a geographic information system (GIS), is used to help make integrated resource management decisions.

Integrated planning is complex and subject to revision, and integrated resource management decisions are often difficult to make. The Rainbow Creek model demonstrates some of this complexity and changeability. For Rainbow Creek, this report traces the complex process of forest harvesting and renewal planning:

- Planning for completion of the PASS 1 roads and harvesting operations.
- Planning forest-renewal operations on the openings created during PASS 1.
- Predicting the economic implications of these plans.
- Finding the alternatives which best integrate harvesting and renewal operations, to achieve the best possible results on the ground at the lowest aggregate costs.
- Confirming that PASS 2 operations will be viable.
- Putting the perfected plan through the steps leading to official approval.

There will never be a final plan for Rainbow Creek. There can only be a series of plans, each updated from the last, and all serving the current needs of the company, the Crown, and all other users of Rainbow Creek’s timber and non-timber resources. The total-chance concept, applied systematically with the best available tools, can assist forest managers in making wise integrated resource management decisions.
INTRODUCTION

In 1983, the Forest Engineering Research Institute of Canada (FERIC) published Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept* (Breadon 1983). It illustrated the orderly planning of timber-harvesting operations for a fictitious drainage called Rainbow Creek, somewhere in British Columbia. The total-chance planning concept was demonstrated, both as a way to avoid the dangers of piecemeal development and to ensure that harvesting operations over the entire drainage would satisfy all recognized objectives.

Since 1983, significant changes in forest management have occurred. New government forest policies and regulations require intensified planning and integration of road development, harvesting, and forest-renewal operations. Silvicultural programs and expenditures have mushroomed. Integrated resource management programs have placed greater emphasis on land uses other than timber extraction. The total-chance concept, originally focused on timber harvesting, obviously should now extend into silviculture and all other resource programs affecting a forest.

The objectives of this 1989 project were to:

- Develop a framework for broadening the total-chance concept to include planning for the other programs which must now complement the timber-development and harvesting plans, within the context of integrated resource management for the 1990s.
- Accomplish this by revisiting Rainbow Creek, observing what has occurred since 1983, and preparing a new, more comprehensive plan for both timber development and forest-renewal operations.
- Prepare a sequel to FERIC Handbook No. 4, illustrating the extended total-chance planning process.

This project complements a 1989-90 series of integrated resource planning seminars conducted throughout British Columbia by FERIC (1990).

More than ever, people in British Columbia want to know what is happening in their forests. Integrated planning is complex and subject to revision, and integrated resource management decisions are often difficult to make. The Rainbow Creek model will demonstrate some of this complexity and changeability, even though it was deliberately kept simple for illustration purposes.

The total-chance concept, applied systematically with the best available tools, can assist forest managers in making wise planning decisions, and in explaining these decisions to others.

RAINBOW CREEK REVISITED

Map 1, reproduced from FERIC Handbook No. 4, shows Rainbow Creek’s topography and original forest cover at a scale of 1:20 000. Additional maps in Handbook No. 4 (not reproduced here) outlined areas to be harvested by different harvesting systems, and the required road network; the road-building and harvesting programs originally planned for each year were colour coded. The road-building program was to span seven years, between Year 0-2 and Year 0+5. The harvesting program was planned to lag approximately two years behind the roads, commencing in Year 0+1 and ending in Year 0+7.

If we assume that the total-chance plan in Handbook No. 4 was approved late in 1983, then road-building would have commenced in 1984, corresponding to Year 0-2. Harvesting would then have started in 1986 (Year 0+1). Harvesting operations would continue through 1992, and then move elsewhere.

Prevention of unnecessary soil disturbance in Rainbow Creek operating areas is a continuing concern. Further road construction, harvesting, and forest-renewal operations will be governed by the new *Interim Harvesting Guidelines for the Interior of British Columbia* (British Columbia Ministry of Forests 1989). The *Interim Harvesting Guidelines* were developed by the Interior Forest Harvesting Council, which consists of representatives from the forest industry, British Columbia Ministry of Forests, Forestry Canada, and FERIC. Following a two-year trial period and subsequent modifications, the *Guidelines* will become Ministry policy.

Although a detailed discussion was not presented in Handbook No. 4, forest-renewal and stand-
improvement operations would have followed harvesting, on schedules appropriate for the treatments prescribed. Under the company's Forest Licence tenure, the company has been undertaking forest-renewal operations, chiefly site preparation and planting, subject to Ministry approval and reimbursement under Section 88 of the Forest Act.

In 1987, the Forest Act (British Columbia Ministry of Forests 1989) was amended to make silvicultural prescriptions, treatments, and costs a licensee responsibility, not a Ministry responsibility, on areas harvested after October 1987. This licensee responsibility would be discharged only after establishment, according to Ministry standards, of a free-growing new crop.

Obviously, an updated total-chance plan for Rainbow Creek is now needed, to integrate forest-renewal with the harvesting operations, and also to satisfy non-forestry requirements which are becoming more sharply defined.

Let us revisit Rainbow Creek, and review what has "happened" since timber-development operations started in 1984. Then let us "plan" what should happen to complete the current cycle of development, harvesting, and forest renewal.

EVENTS SINCE 1984

It is now late in 1989. In an imaginary drainage, it is tempting to relate a story about spectacular wildfires, insect rampages, economic catastrophes, or anti-logging campaigns occurring since the 1983 total-chance plan went into effect. However, this revisitation is intended to illustrate how road-development, harvesting, forest-renewal, and other programs would unfold under more normal circumstances—not exactly according to the original plans, but not so different as to dictate entirely new plans.

Road Construction

Road development and harvesting followed the original planning and scheduling closely. Road construction from 1984 through 1987 proceeded on schedule. In 1988 and 1989, for reasons which will be explained, portions of several branch and spur roads were not built. The complete set of roads built by the end of 1989 is shown on Map 2 (Roads and Harvesting Operations).

Unit costs for road construction gradually increased with inflation. However economies of scale and improvements in the productivity of construction machines partially offset normal inflation rates, resulting in a net increase in road costs of 2% annually. Appendix I lists the roads and bridges built from 1984 to 1989 and shows construction costs as experienced. Roads not yet built (1990+) are also shown, with 1989 estimates of their construction costs.

Harvesting

Harvesting commenced in 1986, and for the most part followed the original total-chance plan through 1989. Prompt 1986 and 1987 salvage harvesting stopped an incipient mountain pine beetle infestation on Blocks 86.09 and 87.03 (Map 2).

Inevitably there were departures from the original plan, and some of these are noteworthy. For example, a 1985 lightning fire burned 6.9 ha of timber on the north slope, which became accessible when road N-2.1 was built, also in 1985. The fire-killed timber was salvaged in 1986 (see Block 86.10 on Map 2), rather than cut normally in 1987 as scheduled. To offset this, a 16.8-ha stand scheduled for cutting in 1986 was left uncut until 1987 (see Block 87.07 on Map 2).

Also, the original plan called for removal of all economically accessible mature timber. Since then, downstream settlement has brought on the need to manage Rainbow Creek as a part of a permanent domestic water supply. Although the selection system prescribed for Blocks 86.02 and 86.03 has successfully protected the integrity and water quality of the main creek, concerns about the extent of further clearcutting upstream were expressed in 1987. In 1988, the company agreed to defer scheduled cutting on selected areas originally scheduled for harvesting between 1989 and 1992.

The areas deferred for domestic water supply consideration are openings with 19, 20, 21, and 22 prefixes (i.e. Blocks 19.01 to 22.01) on Map 2. The new numbering signifies that the blocks will now be left uncut.
until the years 2019 to 2022, some 30 years beyond the dates originally scheduled. At that time they will become part of a PASS 2 harvest. PASS 2 may also include a second cut in Blocks 86.02 and 86.03, which were selectively cut in 1986, and harvesting of presently immature stands which will have matured by then.

Except where needed to reach PASS 1 blocks, roads to the PASS 2 blocks will not be built until about two years before harvesting occurs. Construction of Roads SE-1.1, SE-3.2, S-3.2, and part of S-3 will be deferred until the year 2017.

Although there is an economic cost associated with this lengthy pause in harvesting, the company accepts it. The timber on the PASS 2 blocks is mature, but not decadent, and is not expected to deteriorate. Fortunately, harvesting rights held elsewhere by the company can substitute for the 1989-92 reduction in the Rainbow Creek cut. Other land users and managers are impressed with the company's cooperative attitude and will in turn tend to be cooperative during future dealings.

**Changing Players**

The original total-chance development plan was compiled by “Planning” Peter. Peter has now become “Super” Peter, Area Supervisor responsible for all development, harvesting, and silvicultural operations in Rainbow Creek and several other nearby drainages. Peter relies on “Books” Bill to keep him well informed on the current and projected finances of all parts of the operation. Bill also understands the capabilities of computers.

“Roads” Robbie and “Logs” Louie supervise the road-development and harvesting operations in the field. With their help, “Trees” Tom now does the onward timber-development planning for the area, as well as the planning, prescribing, and field supervision of the growing silvicultural program.

Roads Robbie and Logs Louie depend entirely on contractors for road development and logging in Rainbow Creek. “Cutbank” Charlie and “Hotlogs” Harry were among the original contractors in the drainage. They were successful, grew in size, and joined forces to form C & H Contracting Ltd. C & H now does all road construction and all harvesting, with the exception of cable yarding and small crawler blocks which are handled by “Cables” Chris and “Smallcat” Sam, respectively. “Trucks” Tony handles all log hauling at present. All of these contractors move between Rainbow Creek and other nearby operations, as needed.

Similarly, Super Peter and Trees Tom have developed a network of silvicultural contractors who have local experience in prescribed burning, mechanical site preparation, tree planting, brush control, or juvenile spacing. These include:

- Two local helicopter services, Upland Helicopters Ltd. and Silvicopter Services Ltd., which have slashburning and aerial herbicide spraying expertise.
- C & H Contracting, which often uses its construction and harvesting machines to do slashburning and mechanical site preparation projects on the same blocks that the machines have logged.
- MSP Contracting, which specializes in mechanical site-preparation projects.
- Greenwood Silviculture Contracting, Newforest Silviculture Services, and several other silvicultural contractors which compete for planting, ground herbicide application, brushing, and juvenile spacing contracts.

Trees Tom hopes that his support of local contractors will result in the emergence of longer-term, multifunction, “stewardship” arrangements to ensure balance and continuity of the company’s forest-renewal programs. Under such an arrangement, a single contractor might undertake, on a specified area, all the surveys, site preparation, reforestation, and juvenile tending operations needed to progress from harvesting of the old crop to the free-growing stage of the new crop.

**Integrated Resource Management**

In the early 1980s, Rainbow Creek was included in a Coordinated Resource Management Plan (CRMP), developed cooperatively by forestry, mining, recreation, and range users within a larger area. This plan brought together the interested parties, identified broad use patterns, and served its purpose well; but, it needs to be modernized. Many more people—users of a wide range of resources for livelihood or recreation—are drawn to the Rainbow Creek area by the new road access.

The federal, provincial, and municipal agencies with jurisdiction over resources have changed. The Ministry
of Forests now expects the company to deal directly with those government agencies that might be affected by company activities. Agency personnel have been changing jobs and relocating. Those Peter and his staff deal with most frequently are:

- Timber, engineering, appraisals, silviculture, protection, recreation, range, and other Ministry of Forests people at the Forest Region and Forest District levels.
- Water management, recreational fisheries, wildlife, and other people at the Ministry of Environment Region and District offices.

Peter and his staff realize that no list of interested parties stays the same for long, and that other government, industry, or private agencies are likely to become interested in Rainbow Creek at future developmental stages. They know that demands for detailed information about the company’s plans and activities can only increase. They are seeking a planning vehicle which will help them respond promptly to these demands. More importantly, this planning vehicle must be ready when the company itself needs reliable data as a basis for good forest-management decisions.

Forest-Renewal Operations
When the first total-chance plan was prepared, the classification of Interior forest ecosystems was at an early stage of development. Since then, major advances have been made throughout British Columbia, including work in the Southern Interior (Utzig et al 1986, Lloyd et al 1990). Proper identification and interpretation of the ecosystem has become a basis for prescribing silvicultural treatments. Before a cutting permit is issued, a Preharvest Silviculture Prescription (PHSP) must be prepared by the company and approved by the Forest District manager, for each proposed cutblock or treatment unit therein.

The PHSP is a site-specific detailed document that commits the company to specified silvicultural treatments and results. Licensees are reluctant to prepare highly detailed PHSPs much more than a year or two in advance of harvesting, and thus the silvicultural component of a total-chance plan that spans several years cannot be based entirely on PHSPs. As an alternative, Trees Tom has divided the area into generalized ecological units and planned a series of treatments for each. At the same time, he has developed a set of approximate treatment costs, upon which to base future silviculture budgeting. In the meantime, post-harvest site preparation has started on blocks harvested in 1986, 1987, and 1988, followed by reforestation on some of them.

The entire forest-renewal component of the total-chance plan is described later.

GIS Breakthrough
The maps and calculations in FERIC Handbook No. 4 were prepared by conventional drafting and compilation methods, even though it was obvious that computer technology would be indispensable on large-scale complex applications. Since that time, geographic information system (GIS) packages for forestry applications have been developed for use with relatively inexpensive microcomputers. For example, an investment of about $100 000 might pay for a consultant to select the appropriate GIS system, assemble the necessary data in digital form, and complete a pilot planning project. A further $60 000 might pay to install in-house software and hardware. Finally a team of data collectors, hardware operators, and users within the system—often the same people, changing roles as needed—must become adept at exploiting the new system. The time and money necessary to achieve this will vary widely in relation to the scale and complexity of the GIS application.

Once the system is operating, essential planning can be done with major savings in time and cost. Previously impractical "what-if" trials can now be simulated easily on the computer, and will help in making the best management decisions.

Let us suppose that the company is considering the purchase of the necessary hardware and software for one of these GIS packages. One option of particular interest, developed by the Integrated Resources Branch of the British Columbia Ministry of Forests, is called Harvest Management System (HMS). It is described in detail by Mitchell (1989). HMS is an application of the widely used Terrasoft system, developed and

---

FERIC currently provides a training course for prospective HMS users, under a British Columbia Ministry of Forests contract.
supported by Digital Resources Systems (Canada) Ltd. of Nanaimo, British Columbia.

As Books Bill understands it, the steps needed to make an HMS model of Rainbow Creek are as follows. Using a digitizer, technicians “trace” all map detail (boundaries, topography, environmentally sensitive areas, forest cover, roads, system boundaries, separations by year of harvest) from the original maps into the computer’s memory and onto the colour monitor screen.

In this application, a “cutblock” or “block” is defined as a polygon to be harvested by one harvesting system, in one year. It is surrounded by polygons of differing systems or years, or by areas not to be harvested within the planning period. Each block is given a sequential number. Numerical or text information for each block is supplied by keyboard entries or from tables stored in memory. This information is also linked automatically to the map cells contained within the polygon for the block. The information includes:

- Block number
- Year of harvest
- System name (FELBUNCH, MEDCRAWL, CHOSKID, SMCRWAL, CABYARD, or LGPSKID, as defined later)
- Clearcut or partial cut
- Hauling times, load sizes, and hourly costs
- Share of branch or spur road costs borne by block
- Falling and processing—expected production and direct costs per shift
- Skidding or yarding—expected production and direct costs per shift
- Loading—expected production and direct costs per shift
- Block rehabilitation costs (omitted in this case for simplicity)
- Fixed costs borne by block (omitted in this case for simplicity).

In addition, tables containing net m$^3$/ha and species breakdown for each timber type are stored and used internally to calculate species and total volumes by block. Block area, in hectares, is automatically computed and stored by HMS. As an option, HMS can store customized tables specifying, for each species, estimated percentages by log grade, and corresponding per-m$^3$ values, delivered to mills. From these, timber values are computed for comparison with extraction costs. Summaries of areas, volumes, and costs can be produced for single blocks, and for combinations defined by attributes such as main road, year of cutting, harvest system, or subrange within the entire range of per-m$^3$ cost.

Maps 2 and 3 are examples of HMS plotter output. Appendix II shows a sample of printer output for the 15 blocks remaining for PASS 1 harvesting.

NEW RAINBOW CREEK PLAN, 1990+

Map 2 shows the blocks already harvested up to the end of 1989, in pale blue. Some of these are in early stages of forest renewal; others were harvested recently, and have yet to enter the forest-renewal cycle. The remaining coloured blocks are mature stands still available for cutting (purple for 1990, green for 1991, and brown for 1992). Some of these blocks still require road construction (see roads coloured purple).

Completion of PASS 1 Road Construction

The Rainbow Creek construction program has proceeded largely as originally planned, and should be completed at the end of 1990. Figure 1 illustrates the construction phases and machines employed.

Since 1984, the role of the tracked excavator in road work has expanded, and that of the crawler tractor diminished. However, some of the roads planned for 1990 will be on steep thin-soiled terrain, favouring teamwork by the rock drill and medium crawler. The numbers of shifts required for all machine types, for both construction and road maintenance, are shown later (Table 4a).

---

3When the “block” has been harvested, it becomes an “opening,” awaiting forest renewal.

7The colour codes in Map 2 are the same as those used in FERIC Handbook No. 4 for the years 1990-92, so that the original and revised scheduling can be compared.
The expected cost of each road was originally estimated in 1983. Cutbank Charlie built the 1984 and 1985 roads and bridges under contract, for which the company paid $256,900 and $396,234 respectively. Charlie (now C & H Contracting) continued this construction program on schedule, and for the costs shown in Appendix I, until the end of 1989. Total expenditures to the end of 1989 were $2,155,219, or $37.51/m (i.e. $37,510/km).

In 1988 the company decided to reserve certain watershed buffer areas for PASS 2 harvesting (Map 2, uncoloured blocks). This meant that C & H would finish the 65.85 km of PASS 1 road development in 1990, at an estimated total cost of $2,504,992 or $38.04/m.

![Excavator](image)

![Rock drill](image)

![Crawler](image)

![Front-end loader, with bucket](image)

![Gravel truck](image)

![Grader](image)

*Figure 1. Machines required for constructing and maintaining log-hauling roads.*
Appendix I is a complete listing of all Rainbow Creek roads already built or proposed, showing:

- Year built
- Road name
- Length in metres
- Cost as built (from 1984 to 1989), or estimated future cost (in 1989 dollars)
- Equivalent cost in $/m of length.

From the start of construction, PASS 1 road costs have been written off as follows.

The capital cost of $322 100 for the north main road, the south main road, and the bridges was charged against the total volume harvested during PASS 1. The cost per m$^3$ cut is

\[
\frac{322\,100}{470\,054\,m^3} = 0.69/m^3.
\]

The cost of the main road system will thus be written off by 1992, and not carried on to the conclusion of PASS 2 harvesting.

The cost of branch and spur roads was distributed over the blocks each road developed, on the basis of proportional length needed to access each block. Roads Robbie’s rather lengthy *Lotus* spreadsheet for these calculations is not shown.

Table 1 is a schedule and budget for the completion of all roads. Using 1989 rates for costing, the remainder of PASS 1 roads will be completed in 1990 and will cost $349 773, or $41.64/m. Because they will be built in 1990, however, the discounted cost in 1989 is slightly lower, i.e. $328 425, or $39.10/m.\(^4\)

Roads S-2.5 and N-1 are expected to cost more than average because they will traverse steep terrain and will require extensive rock drilling and blasting.

Table 1 also shows cost estimates for PASS 2 roads, although these roads will not be built until the years 2018-2019. At 1989 rates, their cost is estimated at $118 779, or $31.67/m. All PASS 2 roads will traverse moderate terrain, and will cost less per metre than the average for PASS 1 roads. Since they will not be built for 29-30 years, their discounted present cost is much less, at only $18 488, or $4.93/m.

**Completion of PASS 1 Harvesting**

**Harvesting Systems.** Six harvesting systems were defined for Rainbow Creek in 1983. These were numbered from 1 to 6 at that time, but renamed for *HMS* purposes as follows:

- **FELBUNCH** (FB on Map 2)—Feller-buncher; wheeled grapple skidder to road; manual delimb and buck at roadside (now mechanized with a roadside processor); boom-type loader.
- **MEDCRAWL** (MC on Map 2)—Clearcut or selection system. Hand fall, buck and delimb partly at stump and partly at roadside; medium crawler skid to road; wheeled front-end loader.
- **CHOSKID** (CH on Map 2)—Hand fall; wheeled choker (i.e. line) skidder to landing; manual delimb and buck at landing; wheeled front-end loader.
- **SMCRAWL** (SC on Map 2)—Hand fall; small crawler skid to landing; manual delimb and buck at landing; wheeled front-end loader, heel-boom loader, or self-loading trucks (depending on landing).
- **CABYARD** (CY on Map 2)—Hand fall, delimb and buck partly at stump and partly at roadside; small mobile cable yarder; wheeled front-end loader, heel-boom loader, or self-loading trucks, depending on landing space.
- **LGPSKID** (LS on Map 2)—Hand fall; small crawler primary skid to concentration points; low-ground-pressure tracked skidder swing to landing; manual delimb and buck at landing; wheeled front-end loader. (This system was used with moderate success in 1986, and discontinued thereafter.)

Figures 2 to 7 illustrate the types of equipment used in each system.

\(^4\)Discounting of future expenditures was recommended by Forestry Canada as a device for costing, on an equitable basis, projects to be paid for at differing times in the future. The discounted cost can be regarded as the estimated amount which must be set aside now, in order to pay for a future project. The discount rate, 6.50% real compound interest, was also suggested by Forestry Canada, to reflect expected lending rates, less inflation.
Table 1. Road-Completion Schedule and Budget (1989 Dollars, Discounted to 1989 from Year of Construction)

<table>
<thead>
<tr>
<th>Year and road</th>
<th>Length (m)</th>
<th>Original estimate</th>
<th>1989 estimate</th>
<th>$/m</th>
<th>1989 $</th>
<th>1989 $/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remainder of PASS 1 roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990 S-2.5</td>
<td>1 000</td>
<td>$60 000</td>
<td>$66 245</td>
<td>$66.24</td>
<td>$62 202</td>
<td>$62.20</td>
</tr>
<tr>
<td>1990 S-1 (B)</td>
<td>2 750</td>
<td>$95 200</td>
<td>$105 108</td>
<td>$38.22</td>
<td>$98 693</td>
<td>$35.89</td>
</tr>
<tr>
<td>1990 N-1.1</td>
<td>300</td>
<td>$7 200</td>
<td>$7 949</td>
<td>$26.50</td>
<td>$7 464</td>
<td>$24.88</td>
</tr>
<tr>
<td>1990 S-1.1</td>
<td>1 300</td>
<td>$48 400</td>
<td>$53 438</td>
<td>$41.11</td>
<td>$50 176</td>
<td>$38.60</td>
</tr>
<tr>
<td>1990 S-2.4</td>
<td>900</td>
<td>$19 800</td>
<td>$21 861</td>
<td>$24.29</td>
<td>$20 527</td>
<td>$22.81</td>
</tr>
<tr>
<td>1990 N-1</td>
<td>2 150</td>
<td>$86 200</td>
<td>$95 172</td>
<td>$44.27</td>
<td>$89 363</td>
<td>$41.56</td>
</tr>
<tr>
<td><strong>Total remainder PASS 1</strong></td>
<td>8 400</td>
<td>$316 800</td>
<td>$349 773</td>
<td>$41.64</td>
<td>$328 425</td>
<td>$39.10</td>
</tr>
<tr>
<td>PASS 2 roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018 SE-3.2</td>
<td>800</td>
<td>$31 600</td>
<td>$34 889</td>
<td>$43.61</td>
<td>$5 618</td>
<td>$7.02</td>
</tr>
<tr>
<td>2018 NE-2</td>
<td>200</td>
<td>$4 640</td>
<td>$5 123</td>
<td>$25.61</td>
<td>$825</td>
<td>$4.12</td>
</tr>
<tr>
<td>2018 SE-1.1</td>
<td>700</td>
<td>$12 600</td>
<td>$13 911</td>
<td>$19.87</td>
<td>$2 240</td>
<td>$3.20</td>
</tr>
<tr>
<td><strong>Subtotal 2018 roads</strong></td>
<td>1 700</td>
<td>$48 840</td>
<td>$53 923</td>
<td>$31.72</td>
<td>$8 682</td>
<td>$5.11</td>
</tr>
<tr>
<td>2019 S-3.2</td>
<td>600</td>
<td>$22 629</td>
<td>$24 984</td>
<td>$41.64</td>
<td>$3 777</td>
<td>$6.30</td>
</tr>
<tr>
<td>2019 S-3</td>
<td>700</td>
<td>$15 842</td>
<td>$17 491</td>
<td>$24.99</td>
<td>$2 644</td>
<td>$3.78</td>
</tr>
<tr>
<td>2019 S-2.2</td>
<td>150</td>
<td>$4 500</td>
<td>$4 968</td>
<td>$33.12</td>
<td>$751</td>
<td>$5.01</td>
</tr>
<tr>
<td>2019 S-2.3</td>
<td>350</td>
<td>$8 400</td>
<td>$9 274</td>
<td>$26.50</td>
<td>$1 402</td>
<td>$4.01</td>
</tr>
<tr>
<td>2019 S-3.2</td>
<td>100</td>
<td>$3 771</td>
<td>$4 164</td>
<td>$41.64</td>
<td>$630</td>
<td>$6.30</td>
</tr>
<tr>
<td>2019 S-2.3</td>
<td>150</td>
<td>$3 600</td>
<td>$3 975</td>
<td>$26.50</td>
<td>$601</td>
<td>$4.01</td>
</tr>
<tr>
<td><strong>Subtotal 2019 roads</strong></td>
<td>2 050</td>
<td>$58 742</td>
<td>$64 856</td>
<td>$31.64</td>
<td>$9 805</td>
<td>$4.78</td>
</tr>
<tr>
<td><strong>Total PASS 2 roads</strong></td>
<td>3 750</td>
<td>$107 582</td>
<td>$118 779</td>
<td>$31.67</td>
<td>$18 488</td>
<td>$4.93</td>
</tr>
</tbody>
</table>

Harvest Management System (HMS) Analyses. Trees Tom has been updating the maps and data from the original 1983 total-chance plan, to give Super Peter, Roads Robbie, Logs Louie, and himself a basis for operational decisions, and to comply with Ministry of Forests' planning requirements. Updating has been tedious work. Time has not been available to examine all the development, cutting, and silvicultural options for each new year. After many discussions within the company of this common problem, Tom and Bill were authorized to use and test the Harvest Management System (HMS) in preparing a comprehensive new plan for Rainbow Creek.

Tom and Bill selected Fred’s Forest Consulting Ltd. to install HMS, set up the project, and show both Tom and Bill how to continue operating the system. Fred’s people digitized topographic, forest cover, harvesting, and other detail from the current maps, and set up new timber-cruise, road-cost, harvest-cost, and other input in the form required by HMS. They then produced a series of initial map overlays, similar to those which make up Map 2, to examine on the computer monitor screen. At this stage, proposed blocks were given temporary numbers until a cutting schedule could be established by trial. After this, the final numbers which appear on Map 2 (90.01-22.01) were substituted, matching the permanent numbers assigned to blocks already harvested.

HMS reports, based on area values derived from these map overlays and on parameters input to HMS, were then printed. The first reports were for individual blocks, the next for tentative groupings representing
individual years, and the next for several years combined. Appendix II is a copy of the **HMS** output for the 15 blocks remaining to be harvested during **PASS 1** in 1990, 1991, and 1992.

In order of appearance, the main things Appendix II shows are:

- **Title, dates, parameter tables used, and cost limits**: Blocks with per-m³ costs outside the specified limits can be excluded, if a cost stratification is desired.
- **Attributes**: These are characteristics identified for each block, by which **HMS** has sorted. In this case the first attribute is year of harvest, and 1990, 1991, and 1992 have been selected. No sorting within the other attributes took place.
- **Logging systems selected**: The six Rainbow Creek systems are identified. Other systems stored for other **HMS** projects are excluded.
- **Cutblocks from map TCHANCE**: **HMS** has stored the Rainbow Creek map under the name **TCHANCE**. Data compiled for each of the 15 blocks analyzed are shown by block number, system, area in hectares, volume to cut in m³, production in m³/shift (falling, yarding or skidding, and loading), and shifts required to harvest the volume, again by the three phases. **HMS** calculates the volume in each block by determining the area of each forest type within a block, and then multiplying by per-hectare volumes supplied for each type. The production rates are fed to **HMS**, and the shifts required are calculated by dividing the volume to log by the volume produced per shift, by system and phase.
- **Logging totals**: The same information, by individual cutblocks, is condensed, summarized, and totalled by system (five of the six possible systems are being used in this example).
- **Volumes by species**: **HMS** is supplied with percentage breakdowns by species for each forest type, from which species volumes are compiled for the 15 blocks analyzed. The species occurring in this case are: Bt—**Abies lasiocarpa** (subalpine fir), Cw—**Thuja plicata** (western red cedar), Fd—**Pseudotsuga menziesii** (Douglas-fir), Hw—**Tsuga heterophylla** (western hemlock), Pl—**Pinus contorta**, (lodgepole pine), and S—**Picea** spp. (Interior spruce).

As the summary shows, the remaining fifteen **PASS 1** blocks have about 72,000 m³ of spruce, 51,000 m³ of lodgepole pine, 26,000 m³ of subalpine fir, and lesser volumes of the other species, for a total of 163,054 m³.

**HMS** will provide a further breakdown by log grades, if percentages are supplied. For simplicity in this case, all species were restricted to a single grade—**SAWLOG**—meaning logs suitable for lumber and byproduct chips.

At the right of the table is an artificially inserted column labelled “Value/m³.” This contains per-m³ dollar values, as defined and supplied by the user, for each species and grade. Based on these, the final column was printed by **HMS**, and shows values by species, totalling about $7,529,000.

- **Total logging summary**: This block of results is self-explanatory, with some exceptions.

  “Total spur road cost” is that for branch and spur roads accessing the 15 blocks, both built and unbuilt. This category excludes main road costs, which appear below.

  Most of Appendix II is direct **HMS** printout. However some cost items are not integrally linked to **HMS**, and may change from time to time. In Appendix II, for example, the item marked “Direct costs (above)” is $26.35/m³, and was derived by **HMS**. The cost items below this (“Share of main roads,” $0.69/m³; “Road maintenance,” $1.00/m³; “Area administration,” $3.50/m³; “Stumpage,” $10.00/m³; and “Discounted silv. cost,” $2.33/m³) were calculated “off line,” converted to $/m³ cut, and appended. **HMS** reports tend to be voluminous. These “off line” values can be changed without reactivating **HMS** and printing a new set of reports.

  “Share of main roads” is the $/m³ amount applied to all **PASS 1** blocks to write off the capital cost of the main roads. “Road maintenance” is based on calculations which will appear later (Table 4a). “Administration” and “Stumpage” are not calculated, but based on company records for similar operations.

  The sum of all costs included is $438.87/m³. Total value is $7,529,249, or $46.18 per m³ cut. For woods operations in Rainbow Creek during the remainder of **PASS 1**, a modest profit of $2.31/m³ is predicted.

---

*The derivation of “Discounted Silviculture Cost” is shown at the end of Appendix II. A full discussion of forest-renewal costing appears later in this report.*
Figure 2. FELBUNCH system, suitable for harvesting small timber on moderate terrain.
Figure 3. MEDCRAWL system, suitable for harvesting large timber on broken terrain with adverse skidding.
Figure 4. CHOSKID system, suitable for harvesting a range of timber sizes on moderate terrain with firm or frozen ground.
Figure 5. SMCRWYL system, suitable for harvesting small timber on steep slopes with short skids and small landings.
Figure 6. CABYARD system, best suited for harvesting large timber on steep terrain, but can also be used with small timber.
Figure 7. LGPSKID system, suitable for harvesting small timber on steep and regular terrain.
Harvesting Areas and Volumes. Appendix II represents only a small sample of the information available from HMS.

For Rainbow Creek, similar printed reports by individual blocks, years, systems, and combinations thereof, amounted to about 240 pages. Many of the reports were of the "what-if" variety, printed to check the merits of a particular combination, and then rejected. Still others were merely viewed on the computer monitor, and not printed.

Table 2 is derived from HMS output and shows cutover areas and timber volumes cut or planned, by time interval, harvesting system, and species. Using HMS made it easy to select the following time intervals:

- All past harvesting (1986-89)
- Harvesting planned for the individual years 1990, 1991, and 1992
- Harvesting planned for the remainder of PASS 1 (1990-92 combined)

Table 2 indicates that a reasonably constant species profile can be maintained during future harvesting. Subalpine fir, spruce, and lodgepole pine, making up the Interior spruce-pine-fir (S-P-F) lumber grades and pulp chips, constitute 89% of the total volume to be cut; Douglas-fir, cedar, and hemlock make up the remaining 11%. The proportion of S-P-F rises over time, from 84% for all past harvesting, to 91% for the remainder of PASS 1, and finally to 100% for PASS 2. All of the remaining 13675 m³ of cedar, hemlock, and Douglas-fir (over half of this volume is cedar) will be delivered to mills during 1991 and 1992, unless poor demand at that time strongly dictates otherwise. Because only three years of harvesting remain, not much scope remains for altering cutting plans at Rainbow Creek.

Table 2 also shows the distribution of volumes cut by each harvesting system. For example, the cable yarding (CABYARD) system removed 40% of the volume in all past cutting. The CABYARD proportion is expected to leap to 64% during the remainder of PASS 1, as steep terrain physically curtails the other systems. During PASS 2, the proportion of CABYARD will revert to 52%, with a return to more work being done on terrain where ground skidding (CHOSKID) is feasible.

Table 2 indicates totals of 1711.5 timbered hectares and 524320 m³ harvested or planned for harvesting. The corresponding figures in Handbook No. 4 were 1719 ha and 534000 m³. The difference in the respective area estimates is negligible, at 0.4%. The difference in volume estimates is 2%, resulting from the discovery that volumes harvested in 1986-89 netted 98% of cruise volumes, because of underestimated defect. Estimates of harvesting volume for the remainder of PASS 1 were correspondingly revised downward to 98% of the original cruise estimates.

Harvesting Schedule. Table 3 is a detailed schedule showing areas and volumes to be harvested during the remainder of PASS 1. The information is presented by year, system, block number, and season (summer haul only, versus summer or winter haul, as determined chiefly by road standard and deep-snow limitations on cable yarding).

Blocks 90.03, 90.06, 91.04, 91.05, and 92.04 are clearly summer harvesting operations, and are so marked.

Blocks 90.04 and 90.05 are at high elevation, but are on moderate terrain and served by all-season roads. Hence they are designated all-season, with roads to be plowed if hauling in snow is necessary. The remaining blocks are also served by all-season roads. Logs Louie wants relatively snow-free yarding conditions for CABYARD blocks, but the FELBUNCH, MEDCRAWL, CHOSKID, or SMCRWL systems operate efficiently on frozen ground or snow without causing much site damage.

The proportion of annual volume hauled in summer is 32% in 1990, 26% in 1991, 24% in 1992, and 28% for all three years combined. Because even the upper timbered slopes of the Rainbow Creek drainage are snow-free for at least 40% of each year, no extraordinary acceleration of harvesting during the summer months will be necessary. The implications of Table 3, in terms of shifts and machines required, are examined in the next section.
<table>
<thead>
<tr>
<th>Period</th>
<th>System</th>
<th>Area cut (ha)</th>
<th>Net volume cut</th>
<th>Volume by system (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fd (m³)</td>
<td>Cw (m³)</td>
<td>Hw (m³)</td>
</tr>
<tr>
<td>1986-89 (All past harvesting)</td>
<td>FELBUNCH</td>
<td>82.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MEDCRAWL b</td>
<td>68.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHO SKID</td>
<td>164.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SMCRAWL</td>
<td>217.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>400.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSKID</td>
<td>60.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>994.2</td>
<td>14 937</td>
<td>21 135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>1990</td>
<td>FELBUNCH</td>
<td>43.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHO SKID</td>
<td>40.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SMCRAWL</td>
<td>45.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>117.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>247.6</td>
<td>11 868</td>
<td>35 093</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>16%</td>
<td>47%</td>
</tr>
<tr>
<td>1991</td>
<td>MEDCRAWL</td>
<td>27.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHO SKID</td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>108.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>145.8</td>
<td>1 595</td>
<td>6 741</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>3%</td>
<td>14%</td>
</tr>
<tr>
<td>1992</td>
<td>MEDCRAWL</td>
<td>8.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHO SKID</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>139.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>151.9</td>
<td>1 111</td>
<td>598</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>1990-92 combined (remainder of PASS 1 cut)</td>
<td>FELBUNCH</td>
<td>43.6</td>
<td></td>
<td>1 487</td>
</tr>
<tr>
<td></td>
<td>MEDCRAWL</td>
<td>35.3</td>
<td>309</td>
<td>5 343</td>
</tr>
<tr>
<td></td>
<td>CHO SKID</td>
<td>55.5</td>
<td>1 111</td>
<td>598</td>
</tr>
<tr>
<td></td>
<td>SMCRAWL</td>
<td>45.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>365.4</td>
<td>1 286</td>
<td>1 398</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>545.3</td>
<td>1 595</td>
<td>7 852</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>2019-2022 combined (PASS 2, mature timber deferred)</td>
<td>CHO SKID</td>
<td>78.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABYARD</td>
<td>93.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>172.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>20%</td>
<td>53%</td>
</tr>
<tr>
<td>Total area and volume</td>
<td></td>
<td>1 711.5</td>
<td>16 532</td>
<td>28 987</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% by species</td>
<td>3%</td>
<td>6%</td>
</tr>
</tbody>
</table>

* HMS could report species volumes for each system, if desired.

b MEDCRAWL includes selection system.
Table 3. Harvesting Schedule, Remainder of PASS 1 (1990-92)

<table>
<thead>
<tr>
<th>Year of harvest</th>
<th>System</th>
<th>Opening no.</th>
<th>Summer haul only (ha)</th>
<th>Summer haul only (m³)</th>
<th>Summer or winter haul (ha)</th>
<th>Summer or winter haul (m³)</th>
<th>Total (ha)</th>
<th>Total (m³)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>CHOSKID</td>
<td>90.01</td>
<td>40.7</td>
<td>13 659</td>
<td>40.7</td>
<td>13 659</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>90.02</td>
<td>31.4</td>
<td>10 075</td>
<td>31.4</td>
<td>10 075</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>90.03</td>
<td>81.9</td>
<td>22 909</td>
<td>81.9</td>
<td>22 909</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>FEELBUNCH</td>
<td>90.04</td>
<td>43.6</td>
<td>13 395</td>
<td>43.6</td>
<td>13 395</td>
<td></td>
<td></td>
<td>Snow-plow roads</td>
</tr>
<tr>
<td></td>
<td>SMCRWAL</td>
<td>90.05</td>
<td>45.5</td>
<td>13 389</td>
<td>45.5</td>
<td>13 389</td>
<td></td>
<td></td>
<td>if winter hauling.</td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>90.06</td>
<td>4.5</td>
<td>1 348</td>
<td>4.5</td>
<td>1 348</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>All systems</td>
<td></td>
<td>86.4</td>
<td>24 257</td>
<td>161.2</td>
<td>50 518</td>
<td>247.6</td>
<td>74 775</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% volume by season</td>
<td></td>
<td>32%</td>
<td>68%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>MEDCRAWL</td>
<td>91.01</td>
<td>27.3</td>
<td>10 383</td>
<td>27.3</td>
<td>10 383</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHOSKID</td>
<td>91.02</td>
<td>10.1</td>
<td>3 601</td>
<td>10.1</td>
<td>3 601</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>91.03</td>
<td>66.9</td>
<td>20 925</td>
<td>66.9</td>
<td>20 925</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>91.04</td>
<td>20.1</td>
<td>6 335</td>
<td>20.1</td>
<td>6 335</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>91.05</td>
<td>21.4</td>
<td>5 966</td>
<td>21.4</td>
<td>5 966</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>All systems</td>
<td></td>
<td>41.5</td>
<td>12 301</td>
<td>104.3</td>
<td>34 909</td>
<td>145.8</td>
<td>47 210</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% volume by season</td>
<td></td>
<td>26%</td>
<td>74%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>MEDCRAWL</td>
<td>92.01</td>
<td>8.0</td>
<td>2 421</td>
<td>8.0</td>
<td>2 421</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>92.02</td>
<td>105.4</td>
<td>27 550</td>
<td>105.4</td>
<td>27 550</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHOSKID</td>
<td>92.03</td>
<td>4.7</td>
<td>1 200</td>
<td>4.7</td>
<td>1 200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>92.04</td>
<td>33.8</td>
<td>9 898</td>
<td>33.8</td>
<td>9 898</td>
<td></td>
<td></td>
<td>Summer operation.</td>
</tr>
<tr>
<td></td>
<td>All systems</td>
<td></td>
<td>33.8</td>
<td>9 898</td>
<td>118.1</td>
<td>31 171</td>
<td>151.9</td>
<td>41 069</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% volume by season</td>
<td></td>
<td>24%</td>
<td>76%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990-92 combined</td>
<td>FEELBUNCH</td>
<td></td>
<td>43.6</td>
<td>13 395</td>
<td>43.6</td>
<td>13 395</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MEDCRAWL</td>
<td></td>
<td>35.3</td>
<td>12 804</td>
<td>35.3</td>
<td>12 804</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHOSKID</td>
<td></td>
<td>55.5</td>
<td>18 460</td>
<td>55.5</td>
<td>18 460</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SMCRWAL</td>
<td></td>
<td>45.5</td>
<td>13 389</td>
<td>45.5</td>
<td>13 389</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAYBARD</td>
<td>161.7</td>
<td>46 456</td>
<td>203.7</td>
<td>365.4</td>
<td>105 006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All systems</td>
<td>161.7</td>
<td>46 456</td>
<td>383.6</td>
<td>545.3</td>
<td>163 054</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% volume by season</td>
<td>28%</td>
<td>72%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Harvesting Equipment Requirements and Cost Reconciliation. ***HMS*** reports (see Appendix II) display users' estimates of productivity in terms of m³/shift for each system, by falling (includes delimming and bucking), yarding (includes skidding), and loading phases. These are followed by the calculated numbers of shifts required to complete each phase for the volume shown. For truck hauling, ***HMS*** makes analogous calculations based on estimated production rates. For any given set of blocks, ***HMS*** then computes total direct costs for each phase, by multiplying calculated numbers of shifts by assumed all-found costs per shift. The "Total logging summary," near the end of Appendix II (page 45), shows phase cost estimates derived in this way for the 15 blocks to be harvested in 1990-92.

Table 4 is an independent *Lotus* extension of the same data, used to analyze equipment needs. The table is based on the same productivity and cost estimates as in Appendix II. For the same 1990-92 period, Table 4 shows numbers of shifts required for each year, each harvesting system, and each machine within that system. The information in Table 4 can be used to calculate the number of machines required; Table 5 is an example.